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PALEOSEISMOLOGIC INVESTIGATIONS OF THE HURRICANE FAULT IN SOUTHWESTERN UTAH AND NORTHWESTERN ARIZONA

Final Project Report

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TECHNICAL ABSTRACT

We have completed initial paleoseismologic investigations to evaluate the recency and size of paleoearthquakes and long-term slip rates on the Hurricane fault in southern Utah and northern Arizona (SUNA). Assessing seismic hazard on the Hurricane fault is important because southwestern Utah is experiencing a more than decades-long construction and population boom. The Hurricane fault is a long, west-dipping normal fault with substantial late Cenozoic displacement within the structural and seismic transition between the Colorado Plateau and the Basin and Range province. Previous reconnaissance studies of the fault in northern Arizona and southern Utah had documented evidence of late Quaternary activity. Because of its great length, the Hurricane fault almost certainly ruptures in segments, and abundant geometric and structural characteristics suggestive of fault segmentation exist along its trace. We have focused our initial efforts to explore the behavior of the Hurricane fault on a systematic, detailed reconnaissance of the fault from the Utah-Arizona border north to Cedar City and a detailed investigation of 20 km of the fault from the border southward into Arizona.

Approximately the northern 80 km of the 250-km-long Hurricane fault trends northward through southwestern Utah to Cedar City. Previously, only one site on the Utah portion of the Hurricane fault was recognized with scarps on unconsolidated deposits and only a few locations were known with late Quaternary bedrock scarps. This study identified five additional sites with scarps on unconsolidated deposits and several more bedrock scarps. The youngest deposits displaced are latest Pleistocene or early Holocene across what may be a single-event scarp at one locality, but large, multiple-event scarps are the rule. The number, type, and preservation of scarps along the fault provide insight into possible seismogenic segmentation. The greatest number and best preserved scarps are at the north end of the fault. A previously undocumented graben parallels the Hurricane fault for at least 17 km along Ash Creek Canyon and displaces geologic units in the hanging wall down-to-the-east, increasing apparent tectonic displacement across the Hurricane fault. Displaced alluvial surfaces at Shurtz Creek, tentatively dated on the basis of soil-profile development, provide a minimum slip rate of 0.11 mm/yr for approximately the past 100,000 years. New $^{40}Ar/^{39}Ar$ age estimates for displaced basalt flows erupted from a volcanic center west of the Hurricane fault near Pintura provide slip rate of 0.39 mm/yr over the past 900,000 years. The most recent surface faulting on the Hurricane fault in Utah occurred in the latest Pleistocene or early Holocene, at the north end of the fault. Multiple surface-faulting earthquakes have occurred in the late Quaternary along most, if not all, of the Utah portion of the fault. The potential for developing information about the size and timing of prehistoric surface-faulting earthquakes is good, and the distribution of potential trench sites is such that it should be possible to determine if several prominent bends in the fault are seismogenic boundaries.

In Arizona just south of the Utah border, we conducted the first detailed study involving trenching of the Hurricane fault to estimate paleoseismic parameters. Recurrent vertical slip in the late Quaternary is indicated by numerous unconsolidated alluvial surfaces containing fault scarps of increasing height with increasing surface age. No evidence for significant Quaternary horizontal offset was observed. Cosmogenic isotope dating and soil development analyses provide age estimates of faulted surfaces. Displacements were measured using trench-exposed stratigraphic relationships and topographic scarp profiles. One-dimensional geomorphic profile

modeling of fault scarps provides mass diffusivity values useful for future studies of the region to estimate scarp age. The youngest paleoearthquake along the studied 30 km portion of the Hurricane fault likely occurred 5-10 ka. A 0.60 m vertical displacement during the MRE measured at the trench site at Cottonwood Canyon is likely representative of a 10 km length of fault north of the site, where scarps of similar size and age exist. Another 18 km of fault farther north may have ruptured during this earthquake, but if it did evidence is obscure at the base of the steep Hurricane Cliffs. Statistical relationships between a rupture displacement and the moment magnitude suggest a moment magnitude of 6.6 (6.1-7.0) for the youngest event. At the Cottonwood Canyon site a large fault scarp developed in a 70-125 ka alluvial fan records about 20 m of displacement, yielding a slip rate of 0.15-0.3 mm/yr. The large scarp suggests that the 0.60 m-displacement event is not likely to be typical of previous late Quaternary faulting events recorded at Cottonwood Canyon, because an unlikely number of about 30 such events occurring every 2-4 ka would be required to produce the large scarp. Evidence exists for only one Holocene paleoearthquake, so some previous ruptures on this part of the fault likely were larger than the last and recur at intervals longer than 2-4 ka. The small displacement of the MRE at Cottonwood Canyon may be due to that site's proximity to a potential rupture boundary. Future research on the Hurricane fault in Arizona will be focused the late Quaternary rupture history of the next section of the fault to the south. This should aid in understanding the context of the recent small displacement rupture, and will permit comparison of longer-term slip rates on either side of a potential segment boundary.

NON-TECHNICAL ABSTRACT

The Arizona Geological Survey and the Utah Geological Survey have begun a cooperative research effort to evaluate seismic hazard in southwestern Utah and northwestern Arizona. We have conducted geologic studies that allow us to begin to understand the potential for large, damaging earthquakes on the long, active Hurricane fault zone that cuts through this region. These investigations will significantly improve our understanding of seismic hazard in this rapidly growing region at a time when this information can be incorporated into design standards and building practices.

In Utah, we have visited many sites along the fault and identified several places that are most promising for future, more detailed mapping and trenching investigations. Based on our preliminary work, we believe that most or all of the Hurricane fault in Utah has ruptured in large earthquakes during the past few tens of thousands of years. The youngest paleoearthquake probably occurred on the northern part of the fault about 10,000 years ago. We also dated a basalt that flowed across the Hurricane fault and has subsequently been displaced by faulting. The part of this flow that is east of the Hurricane fault is now about 330 to 400 meters higher than the part of the flow that is west of the fault. Thus, the flow has been displaced by about 350 meters since it was erupted 850,000 years ago. Using these numbers, we estimate that the long-term slip rate on the fault is about 0.3 to 0.4 mm/year. Preliminary estimates of the slip rate over the past 100,000 years or so are quite a bit less, indicating that the fault may have been less active recently.

We have conducted a more detailed investigation of the Hurricane fault in the area of the Utah-Arizona border, where lots of relatively young geologic deposits have been faulted. We have estimated the ages of some of these deposits and measured their displacement. Using this information, we estimate the slip rate on the fault is about 0.15 to 0.3 mm/year over the past 100,000 years or so. We also excavated several trenches across the fault zone to get a better understanding of the age and the size of the youngest paleoearthquake on this part of the fault. We believe that the youngest paleoearthquake occurred between 5,000 and 10,000 years ago. Surface displacement in this event was less than 1 meter, and the rupture length may have been 10 to 15 kilometers, so the magnitude was probably around 6.6. We suspect that sometimes this part of the fault is involved in larger displacement, larger magnitude earthquakes that rupture 30 to 40 kilometers of the fault zone at one time.